THE U.S. STEP-TAS PILOT

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ABSTRACT

In January 2000, the STEP for Aerospace Workshop at JPL brought together representatives from the standards developer, tool vendor and user community. It served as the catalyst for further STEP implementation activities in NASA. The most mature of these activities is the US STEP-TAS pilot. Five US thermal tool vendors are participating. In alphabetical order they are Cullimore and Ring Inc. (Thermal Desktop), Harvard Thermal Inc. (TAS), Network Analysis Inc. (SINDA/ATM), SpaceDesign (TSS), and TAC Inc. (NEVADA).

The scope of this pilot is limited to the development of a prototype bi-directional STEP-TAS interface of defined and limited capability. The word prototype is used in the sense of a feasibility demonstration. This specifically means that the final product is not required to support all capabilities that are typically found in a radiation analysis tool. The prototype is limited to the bi-directional exchange of pre-defined surface geometry and thermal properties.

The current status of this pilot and future plans are reported in this paper.

INTRODUCTION

Before delving into the subject matter it is helpful to gain some perspective. This can be accomplished by viewing the same topic from different angles. Two useful views are the history of STEP and the context STEP provides today for the current pilot activity. But for starters, let us do away with the acronym and spell it out. STEP stands for **St**andard for the **E**xchange of **P**roduct model data. That is quite a construct and it is probably as indicative as anything about the nature of STEP.

Short History of STEP

Without reaching too far into the past, STEP can be viewed as the evolutionary result of many efforts. The following summary has been derived from information in [Ref. 1].

U.S. Efforts

Starting in the 1970s, the American National Standards Institute (ANSI) developed the notion that data should be described independent of particular uses or computer technologies. During the same time frame, the U.S. Airforce developed formal methods of information modeling as part of its Computer Aided Manufacturing (ICAM) program and the Computer-Aided Manufacturing – International (CAM-I) organization developed mathematical presentations of geometry and topology, which contributed significantly to the formal description of Boundary Representation (B-REP) data. At the beginning of the 1980s, the National Bureau of Standards (NBS) formed the IGES organization (IGES = Interim Graphics Exchange Specification) with the goal of developing a common translator for CAD applications. ICAM made a significant contribution to IGES through its Product Data Definition Interface (PDDI), which was to develop a replacement for blueprints.

International Efforts

Problems in the exchange of product data were also recognized early on in Europe. In 1977, the European Association of Aerospace Industries (AECMA) developed a format that allowed the exchange of simple surface geometry. The German Verband der Deutschen Automobil Industrie (VDA) was created in 1982 to address the exchange of free form surfaces and curves needed by the automotive industry. In 1983 the French Standard d'Echange et de Transfer (SET) project was started by Aerospatiale because of the need for a common database capability. And in 1984 the European Commission funded a project called CAD Interfaces (CAD*I), which worked mainly in the exchange of product model data and finite element analysis. In 1987, CAD*I achieved the first ever B-REP solid model exchange between different CAD systems.

The Beginning of STEP

In the mid 80's, many of these efforts had produced results and the focus shifted towards a common solution. From within the IGES organization, the first Product Data Exchange Specification was released in 1984. It was a "proof of concept" to validate methodology and turned eventually into a specification for the international effort led by ISO TC184/SC4 responsible for the development of ISO 10303, informally known as STEP. Since then the enormous number of product data entities has been gathered into many specific Application Protocols, which define the context and scope for various industrial needs.

STEP Today

Today STEP has evolved into over 30 Application Protocols. Some see increasing industrial use, whereas others are still in the developmental stages. A subset of these AP's is particularly suited for the Aerospace industry and is described in [Ref. 2]. This subset includes AP's for System Engineering, Engineering Analysis, 3D Design, and Technical Data Packages. U.S. companies such as Boeing anf Lockheed Martin, are taking the lead to create an interoperating suite of Engineering Analysis (EA) APs.

Here, the STEP AP development pattern has similarities with a traditional design pattern, which starts with a CAD model, followed by engineering analysis. Whereas the 3D Design AP (AP 203) has already found widespread acceptance and is incorporated in most commercial CAD packages, STEP development in the engineering analysis area is most advanced in the finite element structural analysis domain through AP209 – Composite and Metallic Structural Analysis and related design who's first commercial incarnation is available through MSC PATRAN. Currently, ISO TC184/SC4 is engaged in the development of an Engineering Analysis Core Model (EACM) with the goal of harmonization and interoperability of new EA APs, which address aero-thermo/elasticity, dynamics and materials.

In parallel with these developments, the European Space Agency (ESA) in 1996 initiated the development of two STEP-based companion standards called STEP-NRF and STEP-TAS. NRF, the **N**etwork-model **R**esults **F**ormat, is a generic, discipline-independent protocol, which provides representation of engineering objects by network models consisting of nodes and nodal relationships. TAS, the **T**hermal **A**nalysis for **S**pace protocol, specifies the resources necessary for the electronic exchange of data in the domain of thermal control engineering for space applications.

STEP-TAS

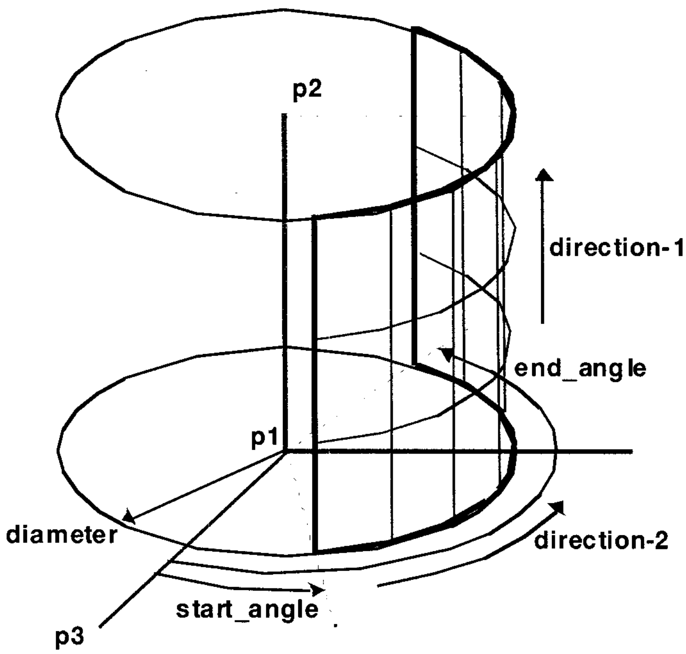
STEP-TAS is a protocol for the definitions of space missions and models used in thermal analysis. The space missions part comprises definitions of orbit, space thermal environment, material property environment and kinematic articulation. The model definition comprises surface geometry (including boolean constructive surface geometry), thermal-radiative properties and meshing, kinematic structure, materials and physical properties. STEP-TAS is a pure extension of STEP-NRF. It adds - or specializes - the specific constructs that are needed for space thermal analysis applications.

The following are within the scope of STEP-TAS:

- The representation of an engineering object by a network model of discrete nodes and relationships between those nodes.
- A hierarchical tree structure of network models and submodels.
- The definition and representation of properties of engineering objects. Both quantitative properties (with numerical value) and descriptive properties (with descriptive content) are supported.
- The representation of values of properties as scalars, vectors and tensors.
- The definition and representation of analysis, test and operation runs, which produce bulk results.

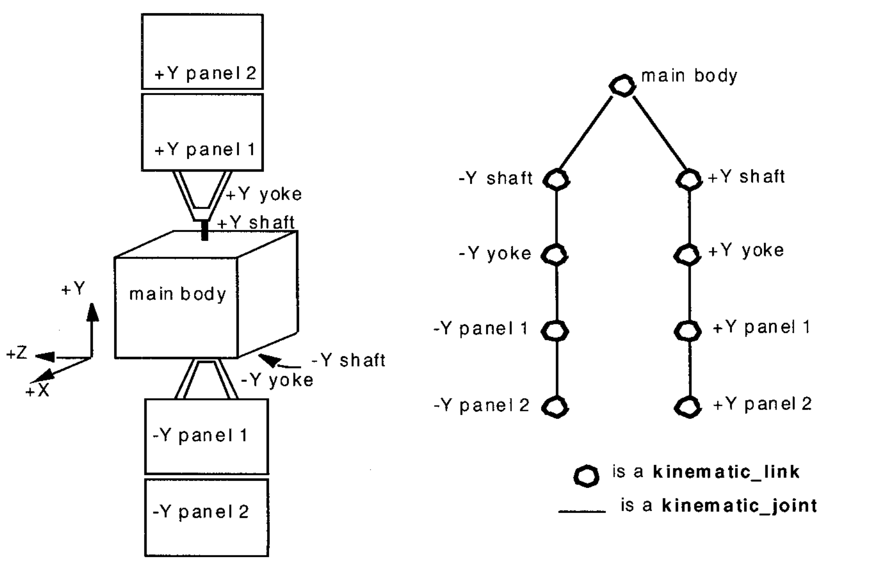
- The definition and representation of product structure, in the form of assembly trees, and the relationships between items in the product structure and in the network model representation.

Examples of three typical STEP-TAS objects are given below in Figure 1 –3 below.



Geometry definition covers triangle, rectangle, quadrilateral, disc, cylinder, cone, sphere, paraboloid, including associated thermo-optical properties.

Figure 1 Example of STEP-TAS geometry definition



(a) Schematic shape model of a typical communications satellite with two fully deployed solar array wings

(b) The corresponding **kinematic_model** presented as a topological graph

Figure 2 Product structure and kinematic structure in STEP-TAS

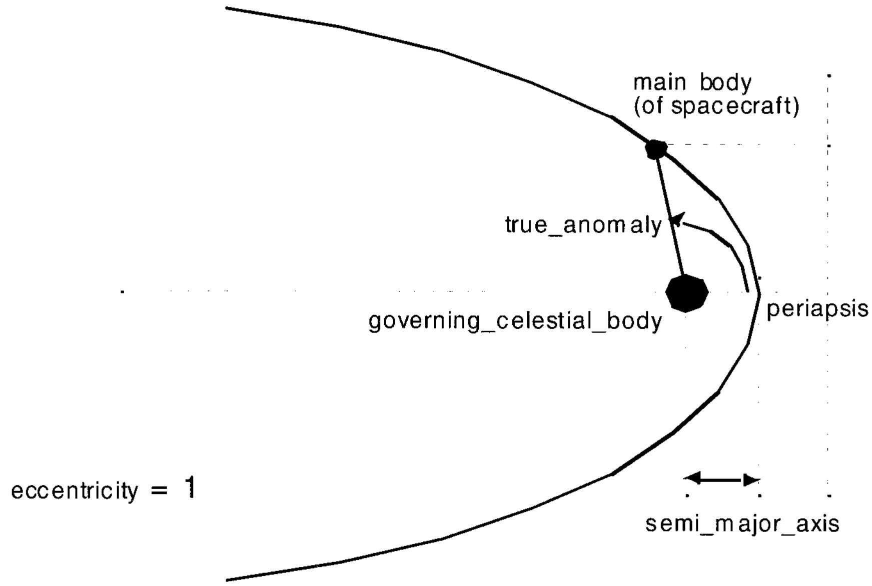


Figure 3 STEP-TAS Orbit Definition

STEP-TAS has passed rigorous testing by ESA and is now industrially implemented in two European analysis tools, ESARAD (ESA/ESTEC) and THERMICA (Matra Marconi Space). A third implementation is planned for CORATHERM (Alcatel Space).

THE U.S. STEP-TAS PILOT

STEP-TAS was first introduced to the U.S. thermal engineering community during TFAWS in 1998. In the two years that have since passed, substantial progress has been made to introduce STEP-TAS in the U.S., culminating in the current pilot activity.

Pilot Scope

The scope of this effort is limited to the development of a prototype bi-directional STEP-TAS interface of defined and limited capability. The word prototype is used in the sense of a feasibility demonstration. This specifically means that the final product is not required to support all activities that are typically found in a radiation model. The prototype is limited to the bi-directional exchange of the surface geometry and thermal properties.

Pilot Objectives

The pilot can be compared to planting a seed. It is intended to raise awareness and to demonstrate the feasibility of STEP-TAS. The hope is that it grows and matures into a full implementation of STEP-TAS into our thermal analysis tools and engineering processes.

The pilot addresses the following objectives:

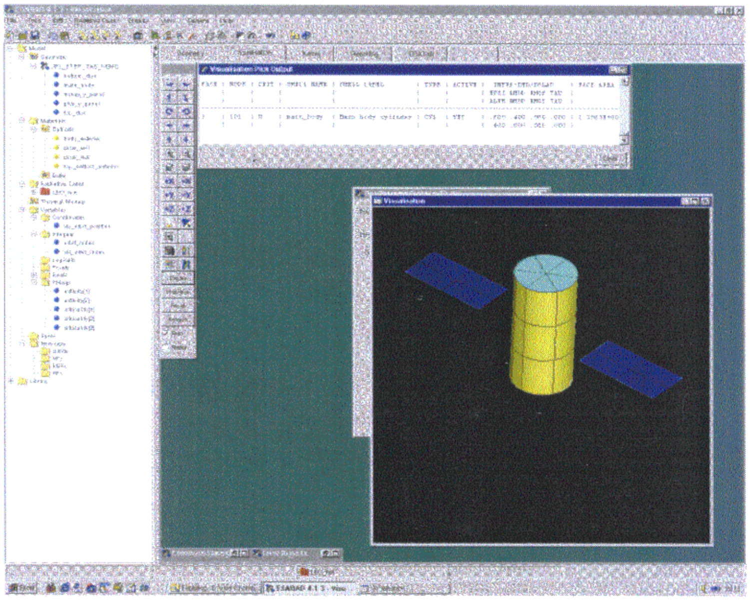
1. Develop a STEP-TAS prototype interface based on SIMULOG/ESA provided APIs.
    - This prototype can either be embedded into the respective radiation analysis tool or a stand-alone product.
    - The prototype shall be bi-directional (tool to STEP-TAS, STEP-TAS to tool).
2. Demonstrate a visual comparison of the native and STEP-TAS based geometry. For the STEP-TAS geometry visualization, apply the visualization tools developed by ESA.

3. The Prototype interface shall be capable of successful bi-directional exchange of the defined geometry. "Successful" is defined as a bi-directional exchange from an analysis tool into STEP and back from STEP into the tool without loss of information. The metric used shall be a defined set of radiation exchange factors calculated before and after the exchange.

4. Once all prototypes have been developed, STEP-TAS models from all developers will be collected and made available to all developers. An attempt shall be made to read and visualize all STEP-TAS files received.

Pilot Geometry

The pilot geometry is purposely kept simple and consists of a cylinder, disks, and quadrilaterals. Figure 4 below shows a rendering of this geometry.



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ISO-10303-21;
HEADER;
...
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#110=TYPE_QUALIFIER('infra_red');
#111=ATR_PROPERTY_NAME('transmittance
        ');
#112=ATR_PROPERTY_QUANTITATIVE(#1
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#113=ATR_PROPERTY_USAGE(#71,#112,#1
        14);
#114=ATR_PROPERTY_MEANING((#109,#1
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#115=SI_UNIT(*,$,.METRE.);
#116=SI_UNIT(*,$,.DEGREE_CELSIUS.);
#117=GLOBAL_UNIT_ASSIGNED_CONTE
        XT('','',(#115,#116));
#118=GLOBAL_UNCERTAINTY_ASSIGNE
        D_CONTEXT('','',(#119,#120));
#119=UNCERTAINTY_MEASURE_WITH_U
        NIT(LENGTH_MEASURE(1.E-
        008),#115
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Figure 4 Pilot Geometry in ESARAD and Excerpt of STEP-TAS File

Pilot Status

Five US thermal tool vendors are participating. In alphabetical order they are Cullimore and Ring Inc. (Thermal Desktop), Harvard Thermal Inc. (TAS), Network Analysis Inc. (SINDA/ATM), SpaceDesign (TSS), and TAC Inc. (NEVADA). The pilot implementation was ongoing at the writing of this paper. The status given below is as of late July 2000.

Status of Cullimore and Ring Inc. (Thermal Desktop)

The STEP-TAS pilot for Thermal Desktop has been completed. In addition to the tasks defined in the pilot, C&R added the capability to import/export triangles, quads, cones, spheres, and paraboloids. The ability to import/export entities that have uneven nodalization has also been implemented in Thermal Desktop. Thermal Desktop already had a TRASYS import/export function, so when you combine this with the STEP-TAS importer, a user will be able to take a TRASYS model and convert it to STEP-TAS or vice versa. The Beta release of Thermal Desktop that contains the STEP-TAS translators will be version 3.3 and will be available in mid August of 2000.

We found the pilot very useful as an introductory process, but would like to see the protocol and the API expanded to handle items such as submodels, uneven nodalization, registers, finite elements, and Thermophysical entities such as thickness, insulators, and contact conductance.

Status of Harvard Thermal Inc. (TAS)

The Baghera viewer is installed and working and we got the STEP-TAS examples to compile and run using the MS VC++ compiler. We had to modify the Include Files so they are compatible with the C++ environment. When we created a class from Example 1 and added it to TAS, TAS crashed.

When we created a simple project and added the class to it, it worked fine. Our conclusion is that there is something in TAS that is incompatible with the STEP-TAS libraries. The problem we have is that there is no way for us to find what it is.

We plan to install our VC++ compiler on a laptop for TFAWS. Maybe we can find the problem. We would like to complete the pilot. What we could do is to write a simpler translator that reads a TAS model file and writes out a STEP-TAS file. We could do the reverse as well. Maybe we will try this before TFAWS.

Status of Network Analysis Inc. (SINDA/ATM)

Network Analysis has added the ability to export a STEP-TAS file from our FEMAP based model builder (SINDA/ATM). This interface was created so any radiation code that can read a STEP-TAS file could interface to SINDA/ATM for solving the thermal radiation/orbital portion of a thermal model. We only support triangles, quads and rectangles since a FEA meshing program like FEMAP divides shapes such as cylinders into flat finite elements. Before adding the STEP-TAS export, we wrote 4 different file types, TRASYS, NEVADA, THERMICA and TSS. If all of these codes had supported STEP, we would have only had to create one type of file export.

Because our product is a graphical model builder, and not a radiation program, importing a STEP-TAS file is not as important to the user of SINDA/ATM. This is because a thermal radiation STEP-TAS model does not contain the complete information that is needed to build a thermal model. The missing information is thickness, thermal conductivity, density and specific. The surfaces (plate geometry) can be imported, and for a small model it is a relatively easy task to assign material properties and thickness to these surfaces. For a large model with many surfaces, this task could be very time consuming. We are currently working the import feature and it should be finished by early August.

The basic flow to interfacing a radiation code to the SINDA/ATM graphical modeler is to export the STEP-TAS radiation file, run the radiation code to produce the radiation conductors and absorbed flux data and finally bring these radiation results back into the thermal model. The STEP-TAS file does not contain the results, so we need to read this data from each radiation code that we support (currently 4 different file formats). Having this data available from all of the radiation codes in a STEP-NRF file would reduce maintaining 4 different interfaces to just one. Also, since file formats sometimes change from one version to the next for a radiation code, we have a total of 8 (4 import and 4 export) formats to keep current. Interfacing to STEP-TAS and STEP-NRF would eliminate us from having the latest version of each radiation code.

In summery, we think exporting STEP-TAS will simplify our SINDA/ATM product, if all of the radiation codes we support add this interface. In order to build a thermal model, the radiation results need to be imported, and this data could come from a STEP/NRF file if the radiation codes produced this file. We currently have to maintain 4 export and 4 import (radiation results) formats, but with STEP-TAS and STEP-NRF this could be reduced to two imports (one for geometry and one for results) and one export and interface to all radiation codes that support this format. Because the STEP-TAS data from a radiation code contains no surface thickness or material properties, it may not be very useful to import a STEP-TAS model into our SINDA/ATM model builder. While one could manually add this missing information for a small model, it may be time consuming for large models.

Status of SpaceDesign (TSS)

With a later start than the other participants, TSS has so far progressed to install the viewing and API software. An initial set of surface primitives has been successfully exported to the STEP-TAS format. It is expected that the pilot is completed for at the time of the TFAWS workshop. A full bi-directional implementation is planned.

Status of TAC Technologies Inc. (NEVADA)

TAC has completed the NEVADA to STEP portion of the code for the basic shapes required by the example file. Other basic shapes have been coded into the translator, but will not be included into production code until the requirements for the STEP-TAS Pilot are met. The STEP to NEVADA code is currently under development. The NEVADA file writing routines are completed with most of the development efforts concentrating on reading and translating the STEP file.

EUROPEAN CONTRIBUTION

The U.S. STEP-TAS pilot is an implementation of information technology developed by several European organizations under the lead of ESA. The obvious contribution is, of course, the development of the STEP-TAS format. But two other developments are essential for a efficient STEP-TAS implementation into U.S. thermal analysis tools. One is the development of high level Application Programming Interfaces (APIs) by SIMULOG. These APIs permit the development of translators without the need to completely understand STEP-TAS on the lowest level of detail. The critical function of these APs is demonstrated in Figure 5 below.

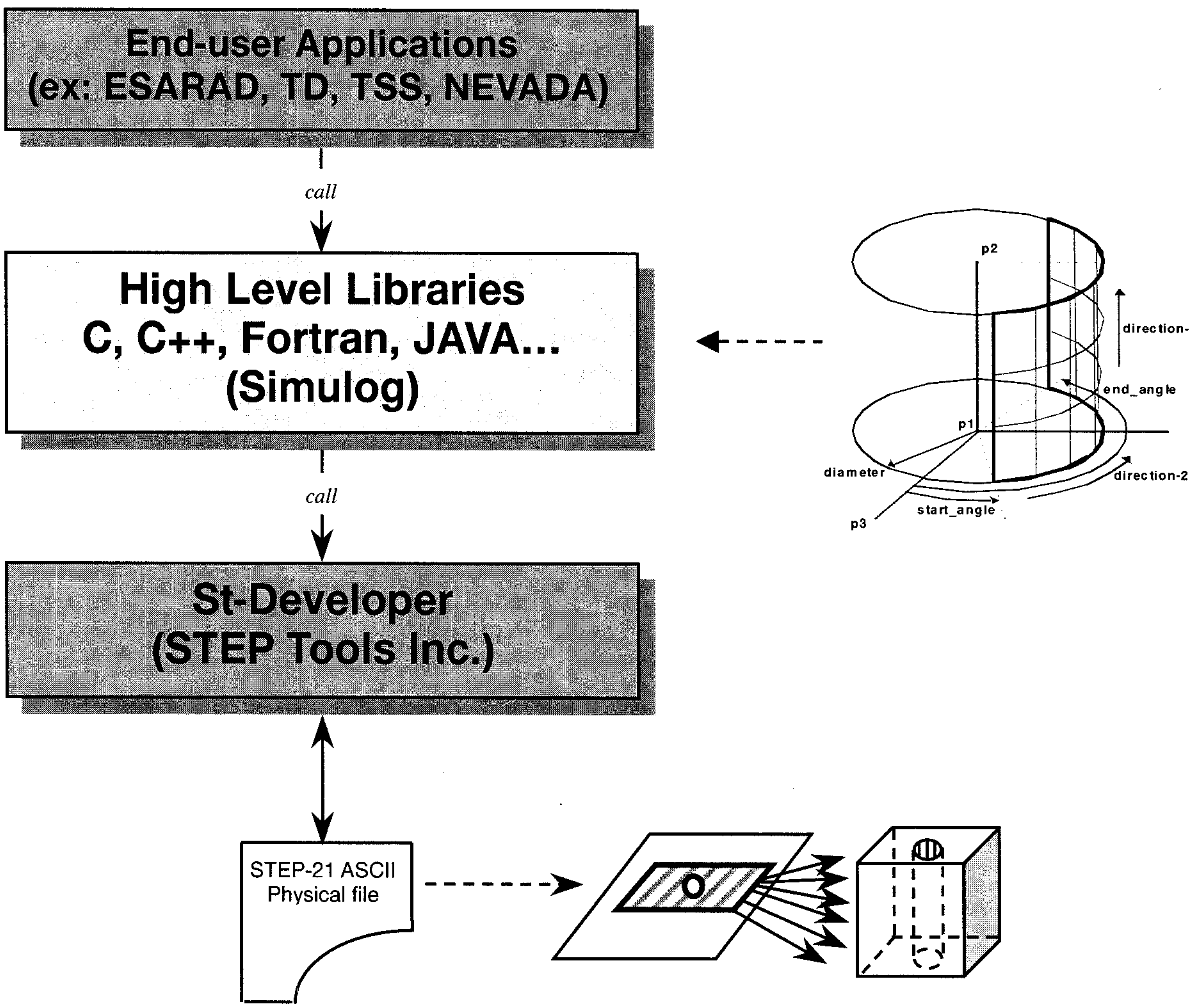

Figure 5 STEP-TAS APIs

The other contribution is Baghera View, a visualization tool developed by SIMULOG under contract to CNES. As can be readily appreciated by anybody who has modeled geometry, visualization is essential for the validation process. An example of Baghera View is shown below in Figure 6.

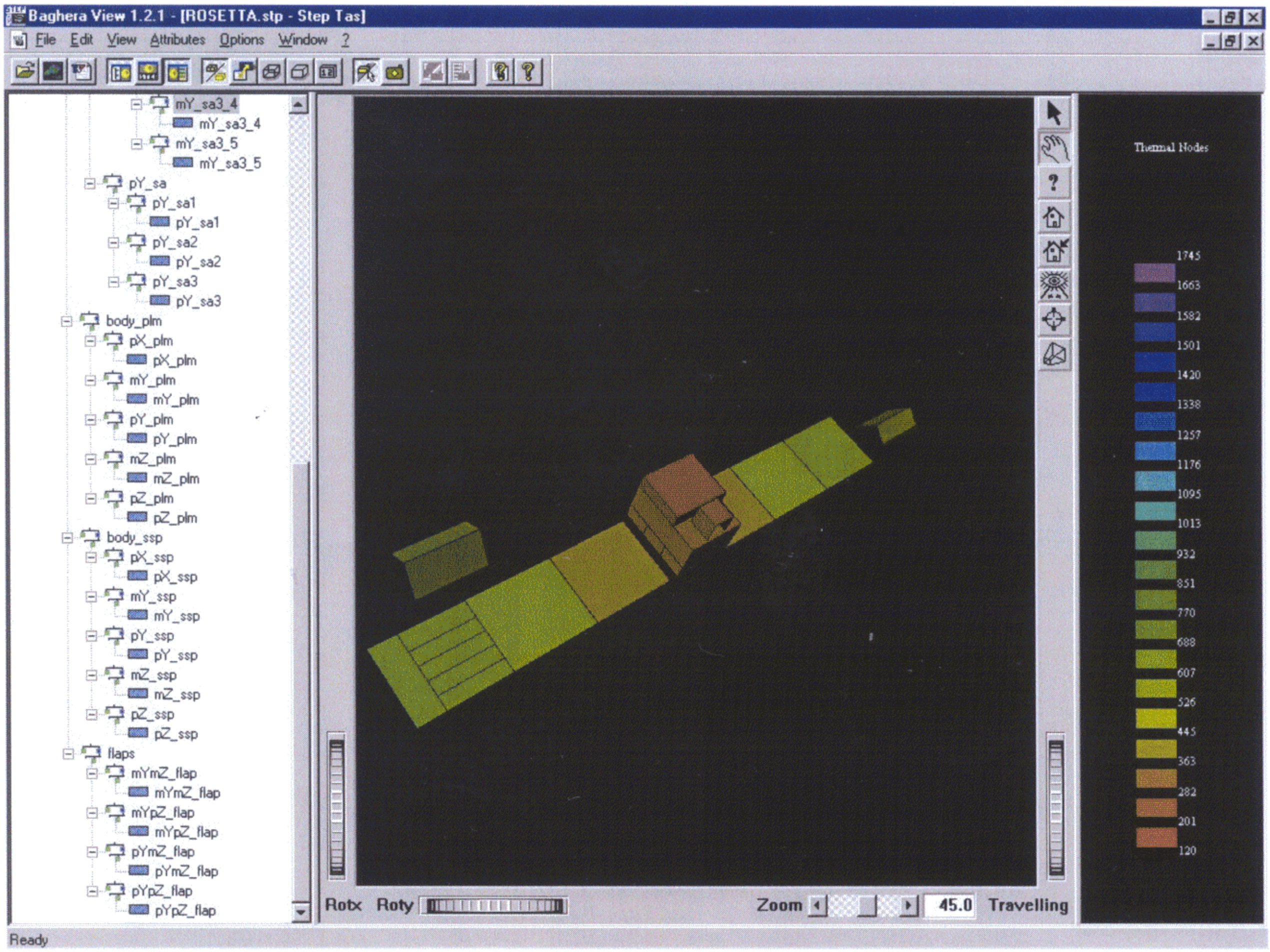

Figure 6 Sample Screen of Baghera View

CONCLUSION

The U.S STEP-TAS pilot holds great promise. Success is already evident at this intermediate stage and it is expected that all pilot objectives will be met. But this pilot is also remarkably successful in demonstrating cooperation between many divers organizations. When it is concluded in a few weeks, the results represent the efforts of five U.S. thermal software vendors, SIMULOG, CNES, ESA and NASA.

The pilot is a significant step towards full interchangeability of thermal radiative models and independence of analysis tools. Once a full implementation of STEP-TAS has been achieved, the results will be liberation from error prone data format translation and a renewed focus on engineering and its underlying processes. The increases in productivity, especially in areas of tight integration of multiple partnering organizations, such as ISS or a new Mars project, are expected to be significant.

And finally, this pilot is hoped to be the first of many more to come, when, starting with STEP-NRF, other engineering analysis application protocols are going to be implemented ...

ACKNOWLEDGEMENTS

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The pilot objectives require a substantial step towards a complete STEP-TAS implementation in the respective thermal analysis tools and could not have been met without additional contributions of resources from the participating tool vendors.

REFERENCES

[Ref. 1] Sharon J. Kemmerer (Editor), The Grand Experience, NIST Special Publication 939

[Ref. 2] Eric Lebegue, Georg Siebes, Charles Stroom, Thermal Analysis Data Exchange between ESA and NASA with STEP, ICES 99ES-39